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CO_2-RICH FLUID INCLUSIONS IN GREENSCHISTS, MIGMATITES, GRANULITES, AND HYDRATED GRANULITES;

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The discovery of pure CO_2 fluid inclusions in granulite facies rocks stimulated models (1,2) attributing a causative role of CO_2 fluids to the formation of granulite facies rocks. The studies of Janardhan et al. (3) and Hansen et al. (4) make a strong case that charnockites in south India were formed by CO_2 infiltration into gneiss; the argument is primarily supported by the occurrence in the charnockites of abundant, "pure" CO_2 fluid inclusions. Hansen et al. (4) and Newton (5) show that a fluid in equilibrium with the mineral assemblages at the calculated metamorphic conditions would be CO_2-rich, and that the fluid inclusions not only are CO_2-rich but also have densities appropriate for the metamorphic conditions. Even though the inclusions appear to be pure CO_2, as much as 30 mole percent H_2O may be present as an optically unresolvable film on the walls of the inclusions (4,6). This allows some reconciliation of the results of the microthermometric data with those of mineral equilibria calculations.

Reports of CO_2-rich fluid inclusions from parageneses for which H_2O-rich fluids have been predicted, however, raise the possibility that the agreement between prediction and observation for the granulite facies terranes may be coincidental. There may be a common process which leads to formation of CO_2-rich secondary inclusions in metamorphic rocks. This possibility needs be tested by well constrained studies of fluid inclusions at all grades of metamorphism and for metamorphic rocks of known tectonic setting.

Examples of discordance of composition of fluid inclusions with predicted composition include the greenschist to amphibolite facies terrane of south-central Maine for which an H_2O-rich synmetamorphic fluid has been predicted (7), leucosomes of migmatites for which X_{H_2O} of the fluid phase had to be greater than 0.7 in order to have melt present at the reported P-T conditions (8), and graphite-bearing granulites for which calculations show that CO_2-rich compositions are not in equilibrium with the metamorphic assemblages (9,10). For the first two examples, CO_2-rich inclusions with densities appropriate for the metamorphic conditions have been reported (11,12,13). In the third case, the CO_2-rich inclusions have lower densities than the fluids would have had at peak metamorphic conditions (9,10). The occurrence and densities of the CO_2-rich inclusions from the greenschist facies rocks of southern Maine (11,12) are remarkably similar to those reported for southern Karnataka, India (4).

In a study of fluid inclusions (14) across the retrograde orthoamphibole isograd in the southern marginal zone of the Archean Limpopo belt of South Africa (15), patterns of composition and density of inclusions were also found to be similar to those reported from other granulite facies terranes, most notably Kerala, India (16): a few apparently pure CO_2 inclusions with densities appropriate for the P-T conditions, many CO_2 inclusions with lower densities, and aqueous inclusions of variable salinity and containing no detectable CO_2. The retrograde orthoamphibole isograd was apparently established by hydration of hot granulite facies rocks that had been thrust over a low grade granite-greenstone terrane (17). During or shortly after thrusting, volatiles generated by post thrusting heating of the footwall greenstones are hypothesized to have entered the granulite facies rocks of the hanging wall, leading to the hydration of the immediately overlying granulites and establishment of the retrograde orthopyroxene isograd. Metamorphic conditions at the isograd require that the equilibrium fluid had there an X_{CO2} of about 0.8. Our results suggest that the hydrating fluid may be represented by secondary CO_2-rich fluid inclusions, which may contain up to 30 mole percent H_2O.

The similarities of fluid inclusion populations are more striking than their differences for the above metamorphic terranes which have markedly different thermal histories. It appears, therefore, that we have some way to go before we can confidently relate, in all cases, entrapment of fluid inclusions to peak metamorphic conditions. This is not to say that fluid inclusion research in metamorphic rocks should not be pursued vigorously. Crawford and Hollister (18) review cases where fluid inclusions have been shown to be related to peak metamorphic conditions. Recently, Olsen (19) related fluid inclusions to conditions during anatexis. And a very productive use of studies of fluid inclusions in metamorphic rocks has been in constraining the post metamorphic exhumation histories of metamorphic terranes (16,20,21,22).

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